

Human Modeling and CAE Based Subjective Seat Comfort Score Correlation

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ABSTRACT

Comfort is a main factor in customer's decision when buying a car. The seat plays a very important role, as it is the interface between occupant and vehicle. Pressure distribution is today's most common approach to characterize seat comfort, but it shows limitations. Analysis of human inter-tissue stress tends to be relevant for an objective comfort assessment.

This paper presents the construction and validation of a CAE human model, based on Magnetic Resonance Imaging scans and in-vivo tests data. Correlation between objective criteria and subjective evaluation will be investigated, comfort performance of a real seat will be predicted.

KEYWORDS: Seat comfort, human model, inter-tissue stress, MRI, Pam-Comfort, CAE-modeling

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1. INTRODUCTION

As part of seat development, the comfort improvement process mainly relies on empirical methods and engineering judgment. This procedure is time consuming and can only be implemented once prototypes have been manufactured. At this stage of the project, design has already been fixed and major modifications can be very expensive.

Improving comfort requires being able to compare design performance to requirements. Comfort is based on a subjective feeling of the test person and therefore it is difficult to objectively quantify it. The method which is commonly used is to measure the contact pressure between the occupant and the seat with sensor mats. This method shows limitations as it only characterizes the 2D loading case, when sitting involves a complex 3D interaction of human inter-tissues in pelvis area. Sensor mats can not exactly fit to non-planar surfaces such as seat cushion A-surface, which may cause disturbances when measuring.

A proper way to characterize comfort is to consider the 3D constraints occurring in occupant's compressed tissues. It is not possible to measure internal stress or strain directly inside the body of a living person. It is possible however to create a virtual human model with biomechanical characteristics thanks to the combination of medical imaging technology, biomechanical engineering and CAE tools. This gives the opportunity to simulate the loading conditions which occur during sitting and to observe their effects on human tissue. Therefore seat comfort can be optimized with CAE tools faster and earlier in the development phase.

A research group of the Institute for Materials Science of Frankfurt University of Applied Sciences together with the Institute for Biomechanical Systems IBIOS has developed a special method which uses a biofidelic human model with in-vivo mechanical tissue properties (BOSS-Model [1; 12]) to characterize discomfort by analyzing stress and strain inside human tissue.

2. MAIN SUBJECT

This study is a pre-investigation that will initiate an ambitious project proposed by Hyundai Motor Europe Technical Center Engineering Design department. The objective is to develop predictive and reliable CAE tools and methods dedicated to seat comfort assessment. This CAE methodology must be easily applicable in serial development so as to efficiently support design teams. For now, the focus is set on the verification of discomfort assessment via a CAE analysis using a human model.

2.1. Project definition

The improvement of comfort first requires clear definition clearly this notion and the factors that are involved. Eg:

2.1.1. Introduction to Seat Comfort

De Looze [2] identifies three characteristics of comfort:

- comfort is a construct of a subjectively-defined personal nature
- comfort is affected by factors of various natures (physical, physiological, psychological)
- comfort is a reaction of a human being to their environment.

Zhang [3] describes the difference between comfort and discomfort. Discomfort is a body's reaction to a physical disturbance from the environment. It is identically perceived by everyone. On the other hand, comfort is related to feeling of well-being and even from the aesthetic appearance of the vehicle interior. This depends on our personal preferences and therefore varies from one person to another. This leads to the conclusion that comfort and discomfort are not their respective opposite, but two distinct entities. It is possible for a system to be considered as comfortable even if there is an obvious discomfort (Fig. 1).

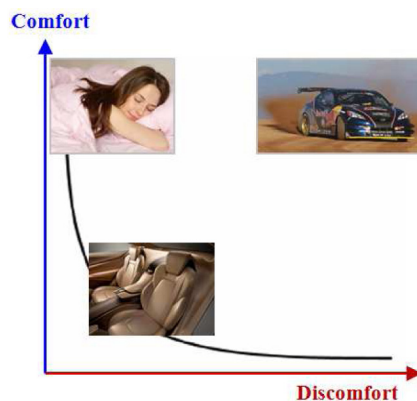


Figure 1. Zhang's comfort model

Consider a race car: the sensations felt by the driver are so intense and enjoyable that it nullifies the extreme discomfort coming from the technical modifications which have been done to increase the car's performance. This principle is summarized by Bubb [4] who declares: "People are ready to suffer for

beauty". On the other hand, a mass production car seat can have a very low discomfort level but there will always be people who won't be satisfied. Because of back pains for example, better support will be required by adding extra foam pads. This highlights the fact that evaluation comfort and discomfort is highly dependent on the individual customer's expectation concerning the product.

Bubb [5] characterized three main factors that impact seat comfort: static discomfort, dynamic discomfort and climate discomfort (Fig. 2).

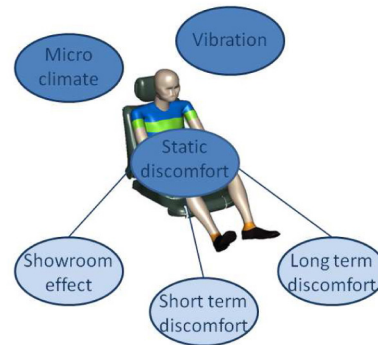


Figure 2. Bubb's representation of seat comfort dimensions [4]

Static discomfort is strongly time dependant and can be divided into three different sub-cases:

- showroom effect (few seconds of sitting)
- short term discomfort (15 to 30 min of sitting)
- long term discomfort (>30min of sitting)

Only short term static discomfort is investigated in this study as it is directly related to physical effects and therefore it can be quantified with measurable criteria. Comfort however involves psychological aspects that cannot be investigated with CAE tools. Long term discomfort, vibration, and climate comfort will be investigated in further projects.

2.1.2. Methodology Definition

Usual objective evaluation methods for discomfort are indirect: physical effects of the occupant on the seat are measured and it is assumed that fulfilling the physical measurements will ensure its satisfied comfort performance. For better prediction accuracy, it has been decided in this study to characterize discomfort with a direct method: physical effects of a seat on the occupant are measured and correspondence to a subjective comfort score is made with the use of a validated comfort evaluation scheme. Therefore it is necessary to use a CAE human model and to analyze loading inside its internal tissue to be able to characterize comfort performance of a seat.

Several CAE human models are available on the market and each one has its own requirements (Fig. 3). It is necessary at first to investigate which one is the most suitable for our study.

	HUMOS 2	THUMS	50%AM (ESI)
MODEL VISUALIZATION			
CAE SOLVER	Radioss	LS-Dyna	Pam-Comfort
STATIC COMFORT	X	X	O
SAFETY	O	O	X

Figure 3. Benchmark of CAE human models for comfort

HUMOS 2 and THUMS models are not adequate for our comfort investigation. Firstly, they do not work with PAMCRASH, which is the preferred CAE code for comfort for Hyundai Motor Company (HMC). Secondly, these solvers are dedicated to safety applications as the prediction of injuries in car collision. There is no information available regarding comfort applications with these two human models.

The 3rd and last available human model is the one developed by ESI and available with the PAMCOMFORT package. Unfortunately, the subject used to generate this CAE model, is not available for any comfort tests. This means that the correlation cannot be properly achieved.

As no current human model is really suited for our study, HMETC has to develop its own. This solution also gives the full control of the validation process.

2.1.3. Project Content

It has been decided to generate a Boss-Model, in collaboration with the company IBIOS that has expertise in modeling of CAE human based on MRI scans and in-vivo tests. A 50%^{ile} employee from HMETC is chosen as test subject for this study. This ensures the possibility to perform validation tests spontaneously and get test data for correlation of discomfort. Moreover, as each MRI scan session has to be conducted out of normal working hours, it is easier to choose somebody who is already involved in the project to try to avoid additional negative influences. The person chosen is 2% smaller and 16% lighter than European 50%^{ile} standards (Table 1).

Table 1. Comparison of anthropometric characteristics

	HMETC subject	50% ^{ile} EU [6]	HIII 50% ^{ile}
Standing height [mm]	1720	1750	1790
Sitting height [mm]	920	915	884
Hip breadth [mm]	348	370	363
Buttock-to-Popliteal length [mm]	463	490	465
Weight [kg]	64	75	72

To investigate the discomfort prediction capabilities of Boss-Model, it has been decided to focus on simple and representative case.

In the sitting situation, 52% of the body load is applied on the cushion. The rest of the load is distributed across the backrest, the steering wheel and the pedals. In the CAE generation phase, we therefore focus on the cushion. The torso is considered as a rigid part and is based on a model previously developed by IBIOS. It is scaled to fit subject's height and is connected to the lower body by coincident nodes.

2.1.4. Project Process

The goal is to investigate the Boss-Model capabilities in term of static discomfort assessment. Objective criteria based on stress and strain measurement are generated and evaluated in terms of reciprocity with body sensations perceived during sitting (Fig. 4).

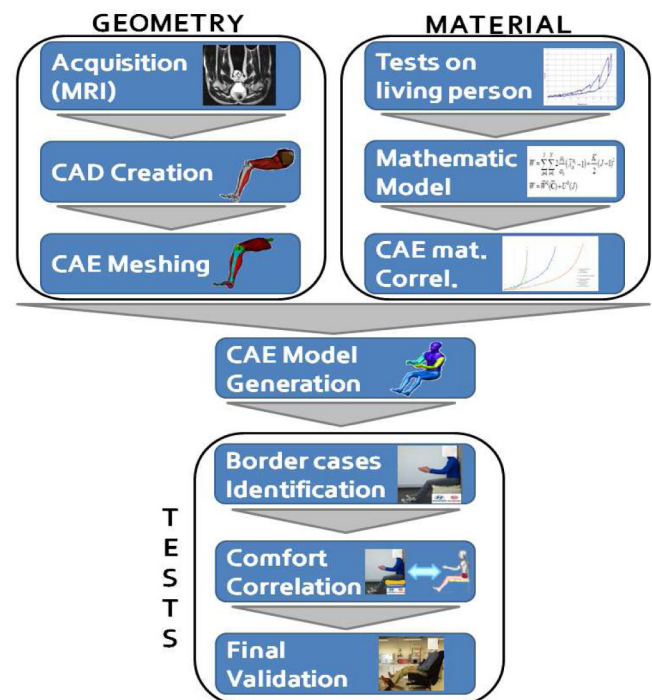


Figure 4. Objective discomfort assessment process

2.2. CAE Model Generation

To guarantee good biofidelic modeling, particular attention must be paid to two aspects: human anatomy and soft tissue materials. The modeling quality of both will determine the correct body deformation and the correct internal load in sitting situation.

2.2.1. Geometric Modeling

Geometry reconstruction is divided into three main steps (Fig. 4):

- Geometry acquisition (MRI scan)
- CAD construction
- CAE meshing